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Assessment of progression in knee osteoarthritis: results of a 1 year study comparing arthroscopy and MRI

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Summary

Objective: The objectives of this study were to determine the sensitivity to change of magnetic resonance imaging (MRI) quantification of chondropathy after 1 year in osteoarthritis of the medial tibiofemoral compartment and to assess the predictive value of subchondral bone marrow edema and bone abnormalities on progression of chondropathy.

Design: Twenty patients with symptomatic knee osteoarthritis of the medial compartment underwent a prospective, longitudinal study. All patients were evaluated the same day at entry and after 1 year by plain weight-bearing radiographs, MRI with a three-dimensional gradient-echo sequence, using a 0.2-T dedicated MR unit, and arthroscopy. The medial tibiofemoral chondropathy was quantified blindly with MRI and arthroscopy using the French Society of Arthroscopy (SFA) score. Presence of subchondral bone marrow edema and bone abnormalities on initial MRI was recorded in order to evaluate their influence on both unchanged and worsened chondropathy after 1 year.

Results: After 1 year, no statistically significant changes were observed with plain radiographs and arthroscopy. At variance, a statistically significant worsening of chondropathy was found with MRI using the SFA-MR score ($P=0.01$). SFA-MR score was the most responsive outcome. Absence of subchondral bone abnormalities and bone marrow edema on initial MR assessment predicted absence of worsening of chondropathy after 1 year.

Conclusion: MRI appears promising for evaluating progression of knee osteoarthritis.

Key words: Magnetic resonance imaging, Arthroscopy, Knee osteoarthritis, Outcome measure.

Introduction

Knee osteoarthritis (OA) is a major cause of pain and disability[1]. Radiological variables are now widely used as outcome measures to determine progression of osteoarthritis of the knee in clinical trials and to describe the course of the disease in epidemiologic studies[2,3]. However, both mild cartilage lesions, and severe and deep cartilage erosions of the knee may remain undetected on weight-bearing radiographs[4–7]. By using arthroscopy, a composite index that takes into account not only location and depth of cartilage lesions but also their extent was required in order to follow and to quantify the evolution of chondropathy of one compartment of the knee joint. Such a composite index of severity of chondropathy was established by the French Society of Arthroscopy (SFA) and is known as the SFA scoring system[8,9]. Reliability, validity, clinical relevance, and sensitivity to change of the arthroscopic SFA scoring system have been validated in populations with mild[8,9] and with severe chondropathy[7]. In a preliminary study, quantification of chondropathy of the knee with MR imaging using the SFA scoring system (called SFA-MR scoring system) was shown to be feasible and well correlated with anatomic cartilage breakdown detected by arthroscopy[10]. However, the sensitivity to change of the SFA-MR score has not yet been assessed.

Although degradation of articular cartilage is the main feature of osteoarthritis, the subchondral bone is also involved either prior to or subsequent to the appearance of chondral alterations[11–14]. In a scintigraphy study using technetium-labelled biphosphonate, a negative bone scan proved to be a powerful negative predictive factor for the development of joint space loss over the following 5 years[11].

The purpose of our study was to determine the sensitivity to change of the MR scoring system in a population of symptomatic patients with medial tibiofemoral osteoarthritis, and to evaluate the ability of subchondral bone marrow edema and bone signal abnormalities to predict subsequent progression of osteoarthritis.

Materials and methods

PATIENTS

Twenty patients (13 women, 7 men; age range, 31–82 years; mean age, 63 years) were included in the study after

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providing informed consent. All patients were examined by the same rheumatologist (XA), and had symptomatic medial tibiofemoral osteoarthritis with indication for a joint lavage by means of arthroscopy. They fulfilled the American College of Rheumatology clinical and radiographic criteria for knee osteoarthritis[15]. Other inclusion criteria were: (1) clinical involvement (pain) of the medial tibiofemoral compartment; (2) symptomatic disease (inadequate pain control certified by prior failure of intraarticular glucocorticoid injection, physical exercises, analgesics, and nonsteroidal anti-inflammatory drugs); (3) mild radiographic osteoarthritis of the medial compartment (medial tibiofemoral joint space ≥2 mm on a weight-bearing extended anteroposterior view), and (4) lack of contraindication for MR imaging and arthroscopic procedures.

STUDY DESIGN

This single-center, prospective, longitudinal study was approved by the ethics committee of our institution. Plain films, MR imaging, and arthroscopy were performed the same day at the initial time point and after 1 year.

CLINICAL CHARACTERISTICS

Demographic data and osteoarthritis variables were recorded for each patient. Demographic data included age, sex, and body mass index. Baseline characteristics of knee osteoarthritis included disease duration. Clinical activity of osteoarthritis was assessed before MRI and arthroscopy using the following variables: (1) pain, evaluated on a 100 mm visual analog scale (VAS)[5] and by the Western Ontario and Mac Master University (WOMAC) osteoarthritis index pain subscale[16], which is a self-administered health status instrument designed specifically for the assessment of lower extremity pain and function in osteoarthritis of the knee or hip; (2) knee stiffness evaluated by the WOMAC stiffness subscale; (3) functional disability, evaluated by the WOMAC function subscale and by Lequesne's functional index[17], which consists of 10 questions regarding the presence of pain or disability and walking distance capacity, and (4) presence of knee effusion.

RADIOGRAPHIC VARIABLES

Radiological evaluation consisted of bilateral anteroposterior weight-bearing knee radiographs with the knee fully extended, and bilateral posteroanterior weight-bearing knee radiographs in flexed position. Radiographs were taken with patients standing on both legs, in a single radiography unit by a staff of three technicians using a standardized technique: cassette placed posterior or anterior to the knee for extended or flexed radiographs, respectively, X-ray beam centered on joint space and inclined to be parallel to the medial tibial plateau with the aid of fluoroscopy, with a tube to film distance of 110 cm. The position of the feet and the angle of flexion and the angle of the X-ray beam were noted and verified for the radiologic evaluation at the 1 year follow-up[18]. The severity of osteoarthritis of the medial tibiofemoral compartment was evaluated using the Kellgren and Lawrence grading system[19], and by measuring the joint space width in millimeters along a vertical line at the narrowest point of the medial compartment using a graduated magnifying glass[9]. The paired radiographs of each patient at entry and after 1 year were read by one investigator (PR) using a blind procedure in which the investigator was unaware of patient identity and chronology of the radiographs.

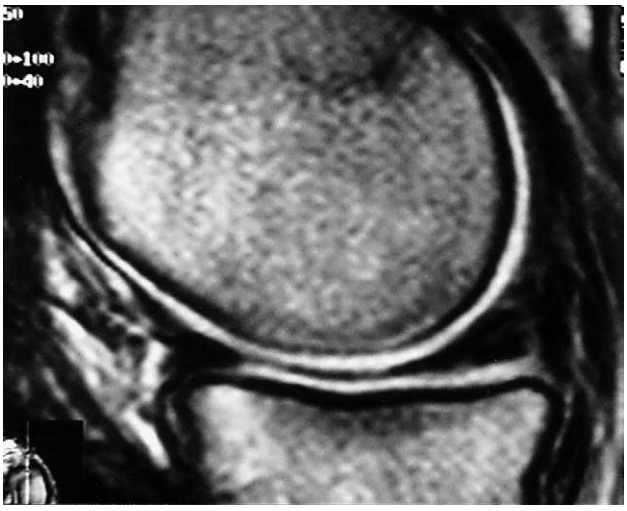


Fig. 1. Sagittal three-dimensional gradient-echo 1.4 mm thick images (60/24, 45° flip angle) shows no cartilage defect (grade 0) of the medial tibiofemoral compartment.

MR DATA COLLECTION

Patients underwent MR imaging with a 0.2 T musculoskeletal dedicated MR unit (Artoscan; Esaote Biomedica, Genoa, Italy). Knees were placed in a receive-only, cylindric solenoid coil. Two successive three-dimensional gradient-echo sequences (repetition time (ms)/echo time (ms), 60/24; 45° flip angle) were acquired in the sagittal and coronal planes with, respectively, 40 and 32 contiguous 1.4 mm-thick sections (Fig. 1). The field of view was 150 mm, the matrix 192×160, and voxels were anisotopic with a size of 0.78×0.94×1.4 mm^3. The acquisition time of each sequence ranged from 5 min 9 s to 6 min 26 s, with one signal acquired. A T2-weighted two-dimensional gradient-echo sequence (TR/TE: 650/16 ms; 35° flip angle) was acquired in the coronal plane with 15 contiguous 4 mm-thick sections. The field of view was 160 mm, the matrix 192×160, the acquisition time was 3 min 32 s, with two signals acquired. A T1-weighted spin-echo (TR/TE: 520/15 ms) was acquired in the coronal plane with 15 contiguous 4 mm-thick sections. The field of view was 160 mm, the matrix 192×160, the acquisition time was 3 min 20 s, with two signals acquired.

ARTHROSCOPIC DATA COLLECTION

The arthroscopic exploration was performed immediately after MR imaging, and focused on the medial tibiofemoral compartment. Arthroscopy was performed by a trained arthroscopist (XA) with use of local anesthesia with epinephrine, without tourniquet hemostasis. A 2.7-mm Storz arthroscope (Storz, Paris, France) with a 30° angled view was used in an inferolateral approach. The medial femoral condyle was explored from 0 to 90° of knee flexion in order to assess cartilage status of its posterior part. The anterior limit of the condyle was defined by the anterior limit of the roof of the intercondylar notch. Each arthroscopic exploration was recorded on videotape.

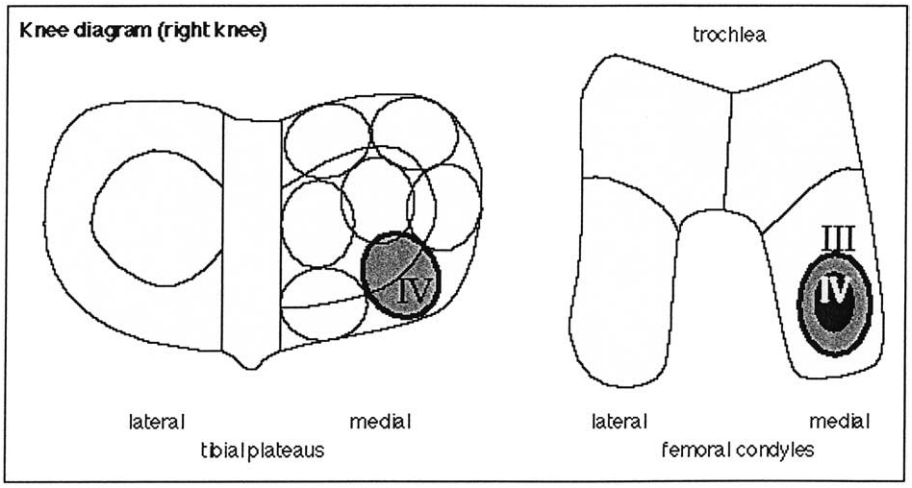


Fig. 2. Example of knee diagram for recording location, depth and extent of articular cartilage lesions of the medial tibiofemoral compartment (right knee) with arthroscopy and MRI. III and IV are grades depth of chondral lesions including: grade 0, normal cartilage; grade I, swelling and/or softening at arthroscopy, focal blistering and intracartilaginous low signal intensity area at MRI; grade II, superficial fibrillations at arthroscopy, superficial irregularities and loss of thickness of less than 50% at MRI; grade III, deep fibrillations or erosions at arthroscopy, deep ulceration with loss of thickness of more than 50% at MRI; grade IV, exposure of subchondral bone.

ARTHROSCOPIC DATA EVALUATION

Qualitative study

The severity of cartilage breakdown was studied for the medial condyle and medial tibial plateau. The depth of cartilage abnormalities was graded 0–IV according to the classification proposed by Beguin and Locker[20]: grade 0, normal cartilage; grade I, swelling and/or softening; grade II, superficial fibrillations; grade III, deep fibrillations down to bone or deep erosions; grade IV, exposure of subchondral bone.

Quantitative study

The first step consisted in recording on an articular diagram of the knee (Fig. 2) the observed chondropathy with three main baseline variables[10]: (1) location: medial femur, and medial tibia; (2) depth based on the classification of chondropathy proposed by Beguin and Locker[10,20]; and (3) size. The size of the lesions was estimated by the arthroscopist as a percentage (from 0 to 100%) of the entire articular surface and was recorded on a special form[5,8]. The SFA score is a composite index of severity of chondropathy taking into account location, depth, and size of cartilage lesions. This score is a continuous variable between 0 and 100 obtained from the medial tibiofemoral compartment as follows[9,10]: SFA score= $S_I \times 0.14 + S_{II} \times 0.34 + S_{III} \times 0.65 + S_{IV} \times 1.00$, where S_I through S_{IV} are the size (expressed as percentage) of grade I–IV lesions. The size (as a percentage) of grade X (where X is 0–IV) corresponds to the mean value of the size of grade X of the medial femoral condyle and the medial tibial plateau. In this study, the SFA score obtained arthroscopically was called the SFA-arthroscopic score. The paired arthroscopic videotapes of each patient at entry and after 1 year were read by one investigator (XA), using a blind procedure in which the investigator was unaware of patient identity and unaware of the chronology of the arthroscopic videotapes. The mean time required for paired reading of one patient's paired videotapes was 45 min.

MR IMAGING DATA EVALUATION

Articular cartilage lesions

Qualitative study. The severity of cartilage lesions was also noted for each articular surface of the medial tibiofemoral compartment. The limits of the condyles were defined to match with the arthroscopic field of investigation: the anterior limit was defined by the anterior limit of the roof of the intercondylar notch[10] and the posterior limit was the posterior end of the condylar cartilage. The depth of cartilage abnormalities were graded 0–IV (MR grade), derived from the arthroscopic classification of Beguin and Locker[10,20] (Fig. 2).

Quantitative study. The SFA-MRI scoring system was derived from the SFA-arthroscopic scoring system. As with arthroscopy, the observed chondropathy was reported on a similar articular diagram of the knee using sagittal and coronal slices[10] (Fig. 2). The SFA-MR score was calculated using the mathematical formula described for arthroscopy and taking into account the depth of chondral lesions, seen on MR images, and their size. The paired MR investigations of each patient at entry and after 1 year were analyzed by one investigator (EP), using a blind procedure in which the investigator was unaware of patient identity and unaware of the chronology of the MR examinations. The mean time required for paired reading of one patient's MRI was half an hour.

Bone marrow edema. Subchondral edema was defined as diffuse and ill-defined areas with intermediate-low signal on T1-weighted images and high signal on T2-weighted images (Fig. 3), and was recorded for each medial tibiofemoral compartment.

Subchondral bone abnormalities. Subchondral bone cyst and sclerosis were defined as circumscribed areas with low signal on T1-weighted images and respectively very high or low signal intensity on T2-weighted images, and were

Fig. 3. Subchondral edema within medial femoral condyle. Gradient echo MR image (TR/TE: 650/16 ms; 35° flip angle) show an ill-defined area in the underlying subchondral bone (between arrows) with low signal on T1 (not showned) and high signal on T2-weighted image.

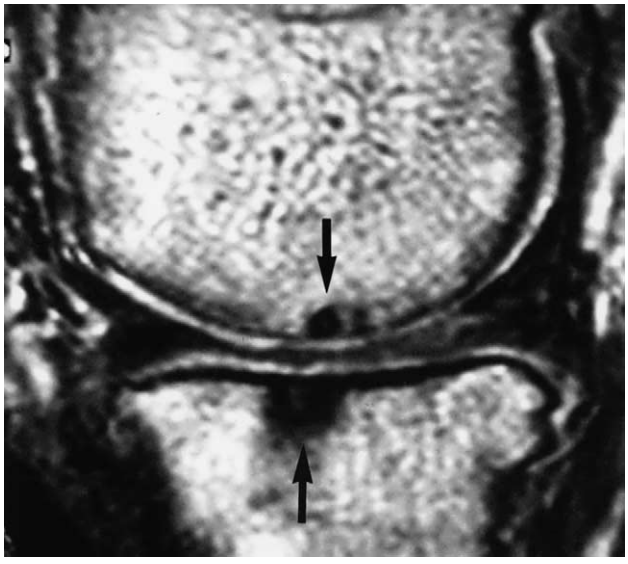


Fig. 4. Sagittal three-dimensional gradient-echo 1.4 mm thick image (60/24, 45° flip angle) shows subchondral cyst within medial femoral condyle and medial tibial plateau (arrows).

recorded for each articular surface of the medial tibiofemoral compartment (Fig. 4).

Statistical analysis

Sensitivity to change. Sensitivity to change was evaluated by comparing severity of chondropathy with plain films, MRI, and arthroscopy in the same patient at entry and after 1 year of follow-up. To detect changes with continuous variables (joint space width, SFA-MR score and SFA-arthroscopic score), we used the Wilcoxon signed rank test to compare values observed at Day 0 and after 1 year, and the standardized response to mean (SRM), calculated as the mean change between 1 year and baseline divided by the standard deviation of the change[21]. A high SRM indicates high sensitivity to change. For all variables, patients were categorized into those having no change and those who had improved or worsened after 1 year (categorical variables). Based on the results of intraobserver reliability of the arthroscopic and MR quantification of chondropathy[7,10], the changes observed in both the SFA-arthroscopic score and SFA-MR score were switched to a categorical variable considered as related to disease evolution and not related to the variability of measurement: improvement was defined by a change (Day 365−Day 0) ≤4.5 and ≤12, worsening by a change >4.5 and >12 for the SFA-arthroscopic score[7] and the SFA-MR score[10], respectively. To detect changes with categorical variables, we used the chi-squared test.

Table I
Characteristics of the patients

Variables	Total (n=20)
Demographic data	
Age (years)	63±9
Sex (M/F)	7/13
Body mass index	30±5
Baseline characteristics	
Knee (right/left)	14/6
Disease duration (years)	5±3
Clinical activity	
Pain (100 mm VAS)	49±16
WOMAC pain (0–4)	2.1±0.6
WOMAC stiffness (0–4)	2.3±0.8
WOMAC function (0–4)	2.0±0.7
Lequesne functional index	9.2±3.5
Knee effusion (yes/no)	8/12
Radiological severity (Kellgren and Lawrence grading)	
O	0
I	0
II	7
III	13
IV	0

BMI, body mass index=weight(kg)/[height(m)]^2; VAS, visual analog scale; WOMAC, Western Ontario and Mac Master University osteoarthritis index.

Bone marrow edema and subchondral bone study. Variation of the SFA-MR score after the 1 year follow-up was studied for the knees with and without bone marrow edema or subchondral bone abnormalities on MRI at entry. Based on the results of intraobserver reliability of the SFA-MR score[10], the SFA-MR score was switched into a categorical variable (unchanged or worsened). The presence of bone marrow edema or subchondral bone abnormalities on initial MR imaging was compared for both unchanged and worsened chondropathy after 1 year.

Results

PATIENT CHARACTERISTICS

The clinical and radiographic characteristics of the patients at entry are summarized in Table I

SENSITIVITY TO CHANGE

The changes in chondropathy of the medial compartment evaluated by plain films, MRI and arthroscopy after 1 year

Table II
Sensitivity to change of radiographic, MRI and arthroscopic evaluation of chondropathy of the medial tibiofemoral compartment after 1 year follow-up (n=20)

	At entry	After 1 year	Change						
			Continuous variable			Continuous variable switched to a categorical variable			
			Δ	*P**	SRM	Improved [*n* (%)]	Unchanged [*n* (%)]	Worsened [*n* (%)]	p**
Radiology									
Joint space width (mm)									
Extension	3.8±1.1	3.8±1.8	−0.1±0.9	>0.05	0.1	0	20 (100)	0	>0.05
Flexed position	2.8±1.7	2.8±1.9	0.0±0.6	>0.05	0	0	20 (100)	0	>0.05
MR imaging									
SFA-MR score	16.3±14.7	22.0±15.6	5.7±5.5	0.01	1.0	0	17 (85)	3 (15)	>0.05
Arthroscopy									
SFA-arthroscopic score	40.8±17.8	41.8±18.4	1.0±4.0	>0.05	0.25	1 (5)	17 (85)	2 (10)	>0.05

Δ, change after 1 year follow-up (Day 365−Day 0); *, Wilcoxon signed rank test; **, chi-squared test; SRM, standardized response to mean calculated as the mean change between 1 year and baseline divided by the standard deviation of the change.

Table III
Correlation between subchondral signal abnormalities (cysts and sclerosis) at entry and deterioration of the cartilage of the medial tibiofemoral compartment after 1 year follow-up (MRI evaluation, n=20)

MRI change after 1 year	Subchondral abnormalities (medial tibiofemoral plateau)		*P*
	Absent (*n*=7)	Present (*n*=13)	
Δ SFA-MR score (continuous variable)	2.0±1.8	7.8±5.8	0.05*
Δ SFA-MR score (continuous variable switched to a categorical variable)	Worsened: 0 Unchanged: 7	Worsened: 3 Unchanged: 10	0.25**

*Mann–Whitney *U* test; **Fisher test.

Table IV
Correlation between bone marrow edema at entry and deterioration of the cartilage of the medial tibiofemoral compartment after 1 year follow-up (MRI evaluation, n=19)

MRI change after 1 year	Bone marrow edema (medial tibiofemoral plateau)		*P*
	Absent (*n*=14)	Present (*n*=5)	
Δ SFA-MR score (continuous variable)	3.8±3.6	10.1±7.4	>0.1*
Δ SFA-MR score (continuous variable switched to a categorical variable)	Worsened: 0 Unchanged: 14	Worsened: 2 Unchanged: 3	0.06**

*Mann–Whitney *U* test; **Fisher test.

follow-up are summarized in Table II. No statistically significant changes were observed with plain radiographs and arthroscopy by using continuous variables or categorical variables. At variance, a statistically significant worsening of chondropathy was found with MR imaging using the SFA-MR score as a continuous variable (p=0.01). Changes of the SFA-MR score switched to a categorical variable were not statistically significant. The continuous SFA-MR score was the most responsive outcome (SRM=1), contrasting with a smaller SRM of the SFA-arthroscopic scoring system (0.25), and a minimum SRM of joint space width measurement (0.1).

SUBCHONDRAL BONE ABNORMALITIES AND BONE MARROW EDEMA

Correlations between subchondral bone abnormalities and bone marrow edema at entry, and deterioration of the cartilage of the medial tibiofemoral compartment after 1 year are summarized in Tables III and IV. For one patient, the presence of artifact prevented the analysis of bone marrow edema (total number of evaluated patients=19). Using the SFA-MR score as a continuous variable, the presence of subchondral bone abnormalities at baseline was correlated with a statistically greater worsening of chondropathy after 1 year (Table III). Using the SFA-MR score as a categorical variable (worsened, unchanged), none of the knees without subchondral signal abnormalities or bone marrow edema worsened. The negative predictive value of bone marrow edema or subchondral bone signal abnormalities on MR at entry was 100%. At variance, presence of bone marrow edema was associated with worsening of chondropathy (*P*=0.06). The positive predictive value was 23% for subchondral bone abnormalities (cyst, osteosclerosis) and 40% for bone marrow edema. No additional subchondral bone abnormalities and bone

marrow edema develop after 1 year. Bone marrow edema of the medial tibial plateau disappeared in two patients. In these two patients, the SFA-MR score and the SFA-arthroscopic score was unchanged after 1 year.

Discussion

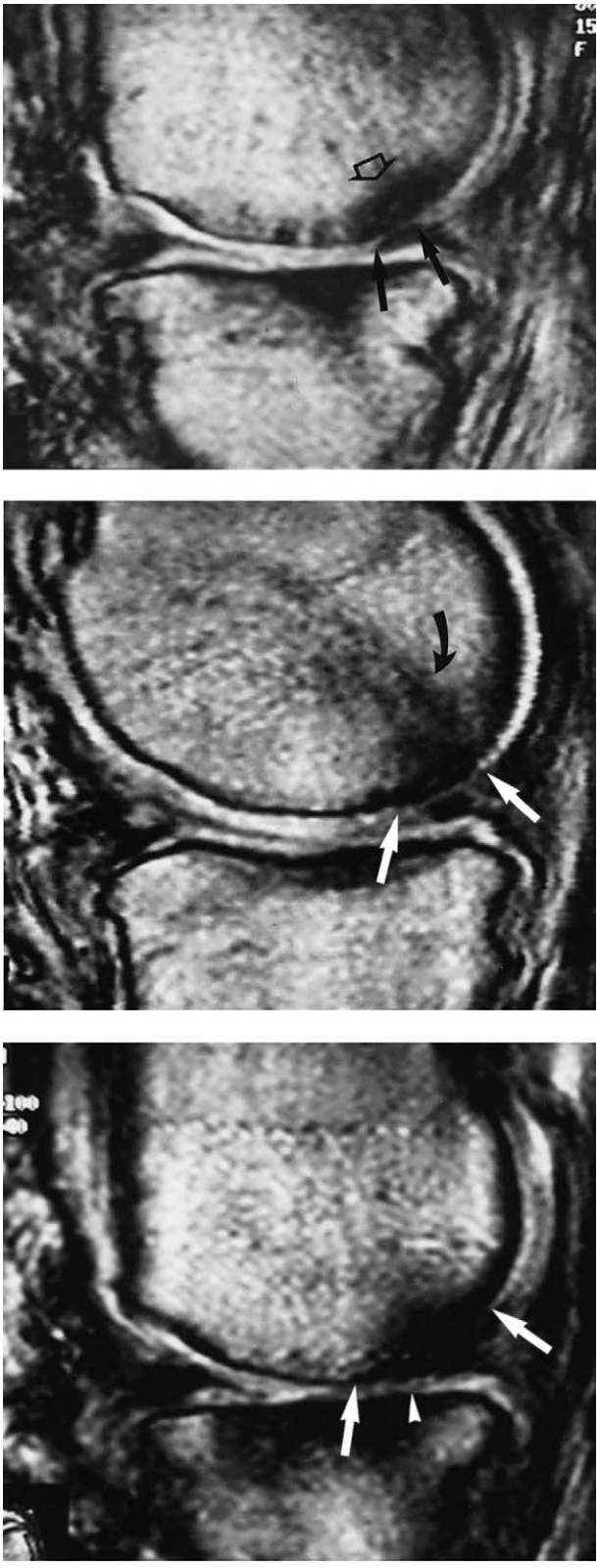
The selected method to assess osteoarthritis of the knee must fulfill the following characteristics: simplicity, validity, reliability, and sensitivity to change[22]. Our preliminary study showed that MRI fulfills the first three criteria[10]. This pilot study suggests that quantification of chondropathy by MRI might be sensitive enough to detect changes within a short period of time (1 year). Sensitivity to change in cartilage breakdown is difficult to demonstrate. After 1 year, no statistically significant changes in radiological and arthroscopic parameters were observed in this study, contrasting with a statistically significant worsening of the SFA-MR score. The absence of significant change for the joint space width measurement after 1 year is consistent with the study of Ravaud *et al.*[23]. Variability in radiographic procedure or in joint positioning may induce modification of joint space width measurements[18]. However, in our study the radiographic technique was standardized and the position of the feet was verified, as proposed by Buckland-Wright[24]. Two previous studies performed in the same arthroscopic center and using SFA-arthroscopic scoring system, found in 41 patients[7] and in 17 patients[25] suffering from medial knee osteoarthritis, a statistically significant worsening of chondropathy after 1 year follow-up. In the present study with 20 patients, we did not find a significant change for this arthroscopic scoring. This discrepancy could be explained by the main limitation of this study, which is its small sample size.

At variance, in the present study we found a significant worsening of the SFA-MR score after 1 year follow-up. However, the level of significance of a mean change is not in itself a measure of the size of the effect, and the detection of statistically significant changes does not imply that such changes are clinically meaningful[26]. On the other hand, changes may be clinically important and relevant but not statistically significant if the sample studied is too small. The SRM indicates the magnitude of change independent of the sample size. Another advantage of SRM is to translate change in various measures into a unit-free numerical quantity, which facilitates comparison between these measures[26]. According to SRM, SFA-MR score seems the most responsive outcome after 1 year follow-up. This result may be explained by the different means used to explore cartilage with MRI and arthroscopy. With MRI, the whole articular surface can easily be investigated with films placed side by side on double view boxes. Reviewing arthroscopy paired videotapes is more time consuming, and detecting small changes in location, depth and size of the chondral surface over time may be more difficult. A quantitative approach to the articular cartilage by focusing on measurements of the volume cartilage[27–30] may be more reproducible but need a dedicated three-dimensional workstation or custom software[27,31] which is not necessary with our global semiquantitative assessment of the cartilage. Moreover, volumetric quantification with three-dimensional reconstruction may be less sensitive than single-section data of the SFA-MR method in identifying tiny focal defects in the cartilage. For this reason, semiquantitative scoring methods may be more reliable for longitudinal evaluation of focal chondral defects than are volume measurements.

Previous studies implicated the subchondral bone in exacerbating the degeneration of the cartilage[11–14]. Radin and Rose proposed that increases in the stiffness of the underlying bone was associated with cartilage degeneration[14]. A healthy joint assists in high load tolerance by deformation and microfractures within the tissue, thus ensuring that energy is dissipated. When subchondral bone thickens, the shock-absorbing capacity of the bone is drastically reduced and shear stress increases between the bone–cartilage interface due to increase of bone stiffness. It was suggested that these bone morphological changes culminate in cartilage fibrillation and subsequent joint degeneration[14,32]. In this study, absence of subchondral bone abnormalities and bone marrow edema on MRI at entry was predictive of no deterioration of chondropathy after 1 year. This high negative predictive value (100%) supports a scintigraphy study[11] using technetium-labelled biphosphonate. They reported that cartilage lesions do not progress significantly on standing weight-bearing radiographs over the ensuing 5 years in the absence of a concomitant increased activity of the bone at entry[11]. Conversely in our study, presence of subchondral bone abnormalities and bone marrow edema on MRI at entry was associated with deterioration of cartilage in, respectively, 23 and 40% of the patients.

The relation between articular cartilage degradation and bone marrow edema is not clear. In a recent study[33], bone marrow lesions were found in 272 of 351 (77.5%) patients with painful knees related to osteoarthritis. This proportion is no so high with our study (five of 19 patients with symptomatic medial tibiofemoral compartment knee osteoarthritis). This discrepancy can be explained by the small sample of the present study. In this study, bone marrow edema ($n=5$) was always associated with subchondral cyst or sclerosis ($n=13$). At variance, subchondral cyst or sclerosis could be present without bone marrow edema (in eight patients over 13). Bone marrow edema and subchondral cyst or sclerosis were always located under cartilage lesions. The size of the bone marrow edema is widely variable with the sequence used and with the strength field of the MR unit[34]. For this reason, size of the bone marrow edema was not measured in the present study, and its correlation with the extent of chondropathy at baseline and 1 year later was not evaluated. A recent study suggests that necrotic bone marrow cells contribute more than edema to these diffuse and ill-defined areas of low signal on T1-weighted images and high signal on T2-weighted images[35]. Whatever may the case, this feature, hypothetically considered to represent bone edema, is typical, easy to recognize, is most likely to reflect bone activity, is strongly associated with the presence of pain in knee osteoarthritis[33], and our study indicates that progression of osteoarthritis is unlikely in the absence of this so-called bone marrow edema and emphasizes the potential importance of subchondral bone in osteoarthritis. Since the purpose of this work was to evaluate the sensitivity to change and the ability to predict progression of osteoarthritis with MRI, we did not correlate the clinical parameters and their change at 1 year with plain films, arthroscopy and MR data.

Several limitations of this pilot study must be noted. First, these results are based on a small sample and need to be confirmed in a large sample. Second, the use of a low-field magnet (0.2 T), which is considered to give inferior image quality is a potential limitation. Moreover, fat suppression, which has been used by most authors to quantify



cartilage is not available at low field strength, the fat and water peaks being too close. However, cartilage appeared spontaneously with a high signal intensity at 0.2 T, and there was high contrast between the cartilage and the subchondral bone and the surrounding soft tissues (Fig. 1). With high field strength, fat suppression is useful to eliminate chemical shift artifacts such as the interface between the cartilage and the subchondral bone. These artifacts are minimized with low-field-strength MR units. Moreover, previous studies have shown that cartilaginous lesions can be evaluated reliably with low-field-strength in patella of cadavers[36] and in patients with symptomatic osteoarthritis of the tibiofemoral joint[10].

Third, with 1.5 T magnets, fast spin echo T2 fat sat images and STIR are much more reliable than T1 or GRE T2* images for showing bone marrow edema. Since at 0.2 T, fat suppression is not possible, we used SE T1 and GRE T2* sequences; this could have an effect on the value of bone marrow edema to predict subsequent progression of osteoarthritis. However, gradient-echo images are insensitive to marrow abnormalities at 1.5 T because of large differences in magnetic susceptibility between trabecular bone and adjacent marrow tissue at high-field strength[34]. This is not the case, however, with low-field MR imaging. At 0.2 T, because of decreased magnetic susceptibility effects, T2-weighted gradient echo imaging offers high contrast-to-noise ratio between water and fat in the marrow cavity[34].

Fourth, since there are difficulties in repositioning the patient for imaging, a single slice [Fig. 5(A,B)] could well not correspond to precisely the same area in the medial compartment. Two successive MR image sequences on the same day after the patient was taken out of the magnet and repositioned, to determine any significant difference in the SFA-MR score, was not performed. However, in this study, we did not compare slice by slice the thickness of the cartilage with two sets of imaging, since we compared an overall quantitative assessment of the entire articular surface of the medial tibiofemoral compartment. Results of thickness measurement are not reproducible without a position marker to identify the same location on the cartilage. Conversely, the position of the knee in the magnet does not interfere with the overall assessment of the entire articular cartilage.

Fifth, we tried to match the anterior limit of the condylar areas explored with MRI and arthroscopy, but the posterior edge of the condyle and the peripheral area of the tibial plateau below the medial meniscus were not always attainable by the arthroscopist. Therefore the area investigated with MR imaging was larger than that visible at arthroscopy, which decreased systematically the SFA-MR score. This is consistent with a preliminary study, which found the SFA-MR scores lower than the SFA-arthroscopic scores[10]. However, the same study showed a statistically significant

Fig. 5. Three-dimensional gradient-echo 1.4 mm thick images (60/24, 45° flip angle) of the medial tibiofemoral compartment at baseline and after 1 year follow-up. (A) Sagittal view at baseline shows a deep ulceration (grade III) of the femoral condyle (between arrows) with a well-defined low signal intensity area in the underlying subchondral bone (open arrow). (B) Sagittal view at baseline slightly medial to level A shows a deep ulceration (grade III) of the femoral condyle (between white arrows) with an ill-defined low-signal-intensity area in the underlying subchondral bone (black curved arrow). (C) Sagittal view after 1 year follow-up shows a deeper ulceration (grade IV) of the femoral condyle (between white arrows). Note the cartilage of the tibial plateau (arrowhead).

correlation between the SFA-MR and SFA-arthroscopic scores[10].

In conclusion, this pilot study suggests that quantification of chondropathy by MRI might be sensitive enough to detect changes within a relatively short period of time, by using the SFA-MR scoring system. If these findings are confirmed, SFA-MRI scoring could be used as an outcome measure of cartilage lesions in clinical trials aimed to evaluate potential structure modifying drugs in osteoarthritis. Moreover, the presence of subchondral bone abnormalities and bone marrow edema may be used in prospective clinical trials as inclusion criteria in order to evaluate patients with potentially active osteoarthritis, which is particularly adapted for testing potential chondroprotective drugs. In daily practice, when MRI is required in knee osteoarthritis, the absence of bone marrow edema or subchondral abnormalities on MRI could indicate for the clinician that the chondral disorder is unlikely to progress over the next year. The clinical relevance of these findings remains to be assessed. Further longitudinal studies with a larger sample are required to confirm these results.

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